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THULE RIOMETER OBSERVATIONS OF POLAR CAP ABSORPTION EVENTS (1962-1972)

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Air Force Cambridge Research Laboratories
L. G. Hanscom Field, Massachusetts

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13. ABSTRACT

Polar Cap Absorption (PCA) events have been observed at Thule, Greenland, (geographic N 76° 33', W 68° 40') using a ground-based riometer for the past decade. The riometer was operated at a fixed frequency of 30 MHz, and utilized a two-element Yagi antenna directed toward the zenith. This report provides information for operational systems personnel and systems designers concerning the mean behavior of PCAs and other aspects of the phenomenon; for example, the extreme cases in duration and magnitude. In addition, included as an appendix are plots of dB absorption and proton flux (obtained from satellites) versus time for each event. The total number of events is 29.

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Abstract

Polar Cap Absorption (PCA) events have been observed at Thule, Greenland, (geographic N 76° 33', W 68° 40') using a ground-based riometer for the past decade. The riometer was operated at a fixed frequency of 30 MHz, and utilized a two-element Yagi antenna directed toward the zenith. This report provides information for operational systems personnel and systems designers concerning the mean behavior of PCAs and other aspects of the phenomenon; for example, the extreme cases in duration and magnitude. In addition, included as an appendix are plots of dB absorption and proton flux (obtained from satellites) versus time for each event. The total number of events is 29.

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Thule Riometer Observations of Polar Cap Absorption Events (1962-1972)

1. INTRODUCTION

For the past 10 years a 30-MHz riometer was operated on a continuous basis at Thule, Greenland. During that time, the riometer was used to observe polar cap absorption (PCA) events. These events were also observed by other experiments such as VLF propagation paths, HF propagation paths, and increases in fmin observed on an ionosonder located in Greenland.

The purpose of this report is to provide information to systems designers and operational systems personnel concerning the behavior of PCA events in such a way as to place this phenomenon in proper perspective with other ionospheric phenomena and geomagnetic disturbances. Provided for reference is a catalog of PCAs observed at Thule, from January 1962 through August 1972. It is important at this time to state that the events presented do not include all possible PCAs observed by other means during that period, nor certainly all the solar proton events observed on various satellites (Shea and Smart, private communication).

(Received for publication 30 January 1973)

The criteria used in selecting PCAs was that the observed vertical absorption on the 30-MHz riometer must equal 0.5 dB above the diurnal and seasonal variation. This is important because the diurnal and seasonal variation in absorption observed at Thule can be 0.8 dB (Cormier, 1970), which exceeds the PCA lower limit of 0.5 dB.

2. MEAN BEHAVIOR OF PCAs AT THULE

During the observation period, a total of 53 PCA events was investigated. Of this total, 11 did not produce events greater than 0.5 dB for two possible reasons: first, the proton flux was of insufficient magnitude to produce an observable effect on the riometer recording; and secondly, the seasonal effect (darkness during the winter months) may have contributed to a reading of minimal absorption, the mechanism of the nighttime recovery phenomenon (Reid, 1966; Leinbach, 1967). Of the remaining, 13 were ambiguous for reasons such as equipment malfunction, antenna problems, or data loss. However, the whole event period was not necessarily lost. It is constructive to add at this time that the large PCA events greater than 10 dB would certainly not be included in the questionable category, because large PCA events are unambiguous on riometer recordings. The 29 remaining events (see Table 1) illustrated in the Appendix are unambiguous events; they are used to obtain the mean behavior of PCA events. In Table 1, the following information is given: date of onset time; time in UT of the onset, max, and end time; observed magnitude of dB absorption on the riometer; and proton flux observed by satellites.

Table 1. List of PCA Events

Date	Time (UT) Begin	Time (UT) Max	Time (UT) End	Riometer Max dB	Protons/cm^2 sec ster Max Proton Flux
1962					
Feb 1	2000 1 Feb	1400 2 Feb	2100 2 Feb	2.8	2,600E > 1.4 MeV
1963					
Feb 9	2200 9 Feb	1100 10 Feb		2.4	0.35E > 10 MeV
1964			NONE REPORTED		
1965			NONE GREATER THAN 0.5 dB		

Table 1. List of PCA Events (Cont)

Date	Time (UT) Begin	Max	End	Riometer Max dB	Protons/cm^2 sec ster Max Proton Flux
1966					
Mar 24	0900 24 Mar	1100 24 Mar	1800 24 Mar	0.6	15E≥20 MeV
Jul 7	0100 7 Jul	1200 7 Jul	2100 8 Jul	2.1	28E≥15 MeV
Aug 28	1900 28 Aug	0100 20 Aug	0300 31 Aug	2.4	16E≥20 MeV
Sep 2	0800 2 Sep	1300 3 Sep	2000 6 Sep	14.0	1,300E≥15 MeV
1967					
Jan 28	1500 28 Jan	1800 29 Jan	0300 31 Jan	2.7	0.6E≥15 MeV
Mar 11	1900 11 Mar	1900 12 Mar	2000 12 Mar	1.0	
May 24	0400 24 May	1400 25 May	0100 27 May	8.3	980E≥10 MeV
May 28	0600 28 May	0900 28 May	1700 30 May	4.1	115E≥10 MeV
Jun 6	0900 6 Jun	0200 7 Jun	2200 8 Jun	1.8	20E≥10 MeV
1968					
Jun 9	1000 9 Jun	0800 10 Jun	0100 12 Jun	6.5	354E≥10 MeV
Oct 31	1200 31 Oct	1900 2 Nov	0600 3 Nov	2.5	133E≥10 MeV
Nov 18	1400 18 Nov	1600 19 Nov	1900 20 Nov	1.7	849E≥10 MeV
1969					
Jan 24	1400 24 Jan	1700 24 Jan	0900 25 Jan	1.2	3E≥10 MeV
Feb 25	1200 25 Feb	1500 25 Feb	0100 26 Feb	2.1	88E≥10 MeV
Mar 30	1100 30 Mar	1900 30 Mar		1.3	26E≥10 MeV
Apr 11	1300 11 Apr	13 Apr	0000 21 Apr	> 16	1,348E≥10 MeV
Nov 2	1200 2 Nov	1600 2 Nov	0200 5 Nov		1,317E≥10 MeV
1970					
Mar 7	1200 7 Mar	1500 28 Mar	2100 8 Mar	5.1	93E≥10 MeV
1971					
Jan 25	0300 25 Jan	1600 26 Jan	2000 27 Jan	2.3	1,170E≥10 MeV
Apr 6	1200 6 Apr	1800 6 Apr	0200 8 Apr	2.2	51E≥10 MeV
Apr 21	0000 21 Apr	0800 21 Apr	1000 21 Apr	0.9	3E≥10 MeV
Sep 1	2200 1 Sep	1000 2 Sep	0400 5 Sep	5.2	245E≥10 MeV
Dec 17	0100 17 Dec	0800 17 Dec	1600 17 Dec	1.9	
1972					
Jan 20	1500 20 Jan	1100 21 Jan	0500 22 Jan	1.8	
May 28	2300 28 May	2300 29 May	0300 1 Jun	2.2	39E≥10 MeV
Aug 3	0000 3 Aug	4 Aug		> 16	
Aug 7	1800 7 Aug	2300 8 Aug	0100 11 Aug	14	

The mean behavior was obtained to help answer questions asked by many investigators, for example: How many PCAs can one expect a year? How long does a PCA last? How often can severe PCAs be expected to occur? During what percentage of time can one expect to have appreciable HF absorption phenomena?

The mean duration of a PCA event is 63.6 hours. The mean magnitude is 4.0 dB. The mean duration of the proton flux is 84.3 hours. The proton flux was cut off when the flux reached 1 proton/cm^2 sec ster for energies of $E \geq 10$ MeV. The longest event occurred on 11 April 1969, which lasted 203 hours. The shortest event was 9 hours observed on 24 March 1966.

Another parameter of interest to system designers is the amount of time a particular absorption level is exceeded, which leads to the amount of power required to account for the expected absorption. The levels chosen in this report are $\geq$ 10 dB, $\geq$ 5 dB, $\geq$ 3 dB, $\geq$ 2 dB, and $\geq$ 1 dB. The total number of hours of PCA events observed during the 29 events is 1853 hours or 76.8 days. The percentages of the total time of occurrence for each level are as follows:

$\geq$ 10 dB - 3.6%, $\geq$ 5 dB - 11.3%
$\geq$ 3 dB - 17.9%, $\geq$ 2 dB - 29.0%
$\geq$ 1 dB - 57.3%

When considering the foregoing percentages, one must note that the hours of absorption are not evenly distributed over the report period. To illustrate this, representative levels are shown in the Figure 1 histogram. The most striking feature of this figure is the lack of any events during the year 1964 and 1965. During 1964, no reference to any appreciable solar proton event was reported; during 1965, no absorption event which exceeded 0.5 dB was detected on the riometer. Large events greater than 10 dB were observed only in three distinct years; namely, 1966, 1969, and 1972.

The relationship between the proton flux curve observed on satellites and the riometer absorption as reported by Judy and Adams (1969), namely, $J = K A^2$ where J = proton flux, A = riometer absorption and K is 8 ± 2 was investigated so as to verify its reliability. The relationship was shown to be very good for the months of March through September. The months of April and October do not behave systematically; that is, some follow the relationship and some do not. The winter months show no consistent behavior. Of course, the data sample is too small to draw definite conclusions concerning the relationship.

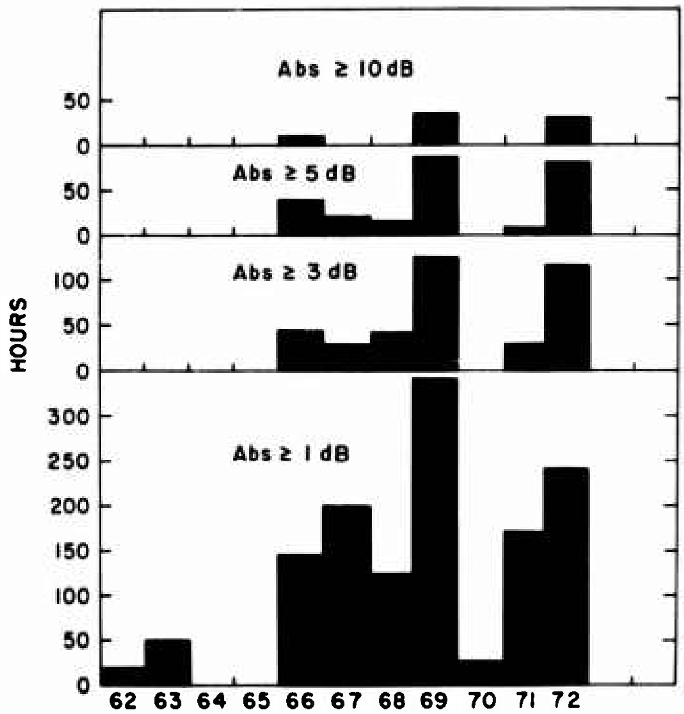

Figure 1. Hours of Absorption Observed on 30-MHz Riometer at Thule, Greenland, for Selected Levels

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Appendix

Twenty-nine PCA Events Used to Obtain Mean Behavior

Included are plots for the 29 PCA events listed in Table 1 and used in the histogram of Figure 1. The graphs show plots of dB absorption versus universal time for the 30-MHz Thule riometer. Some graphs contain plots of the square root of the proton flux of energies ≥ 10 MeV as observed from various satellites.* The events prior to 24 May 1967 do not have proton flux data readily available in the ESSA data pamphlets. The August 1972 events do not have proton flux data available as yet in the ESSA data pamphlets of the comprehensive series.

Included on the plots is the calculated value of expected absorption (represented by the letter x) using the Judy and Adams relationship of $J = KA^2$. In these cases, the value for K is 8.

The mean behavior as discussed in the foregoing is presented as a guide to operational personnel and, in particular, systems designers. For instance, if one needs real-time information, a system or systems must be designed to operate in the extreme cases, adding to the cost of the system. If the information could be delayed a number of hours until the severe disturbance was terminated, then one could design the system for the mean-behavior magnitude, that is, about 4 dB.

*The proton flux data were obtained from the Solar Geophysical Data, IER-FB-Part II, 282, 292, 298, and 300; Comprehensive Reports 301, 303, 309, 313, 328, 336, 338, and 339, U.S. Department of Commerce, Environmental Sciences Services Administration.

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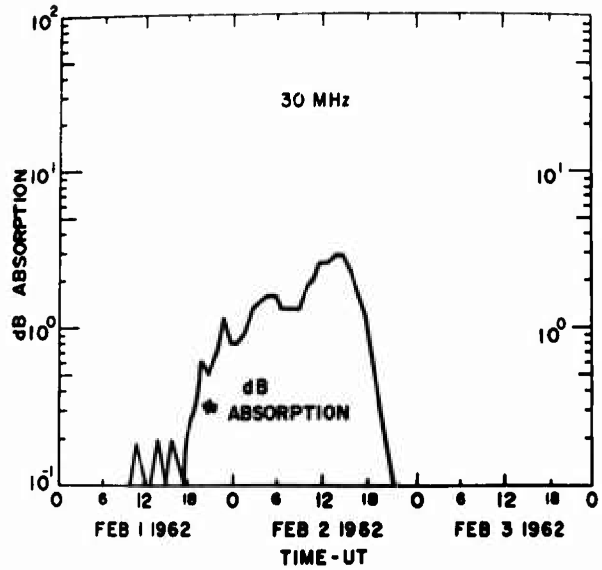
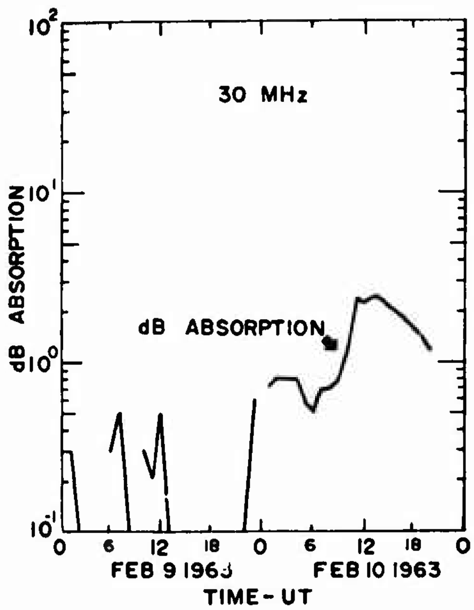
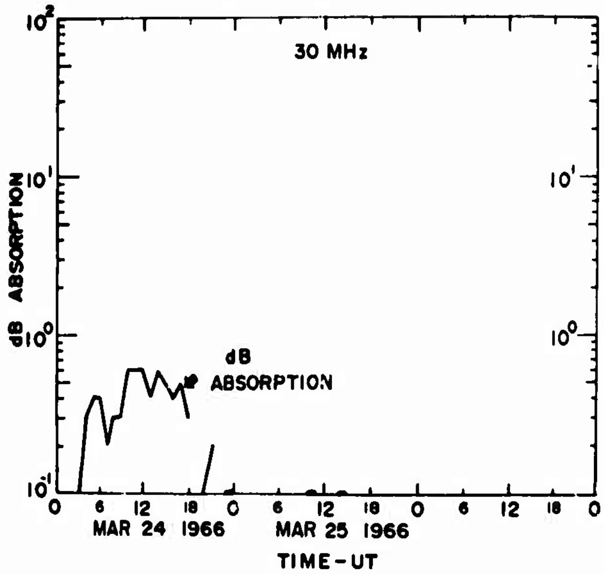


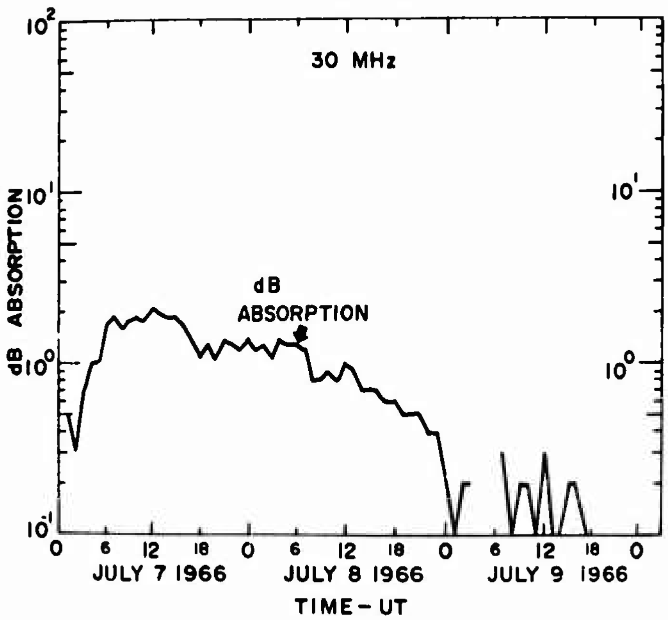
Plot 1 Feb. 1, 1962



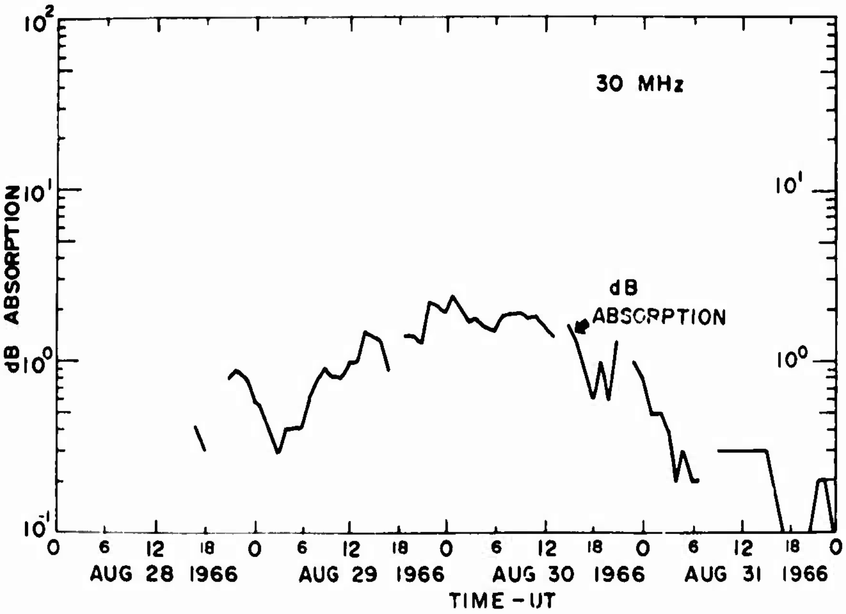
Plot 2 Feb. 9, 1962



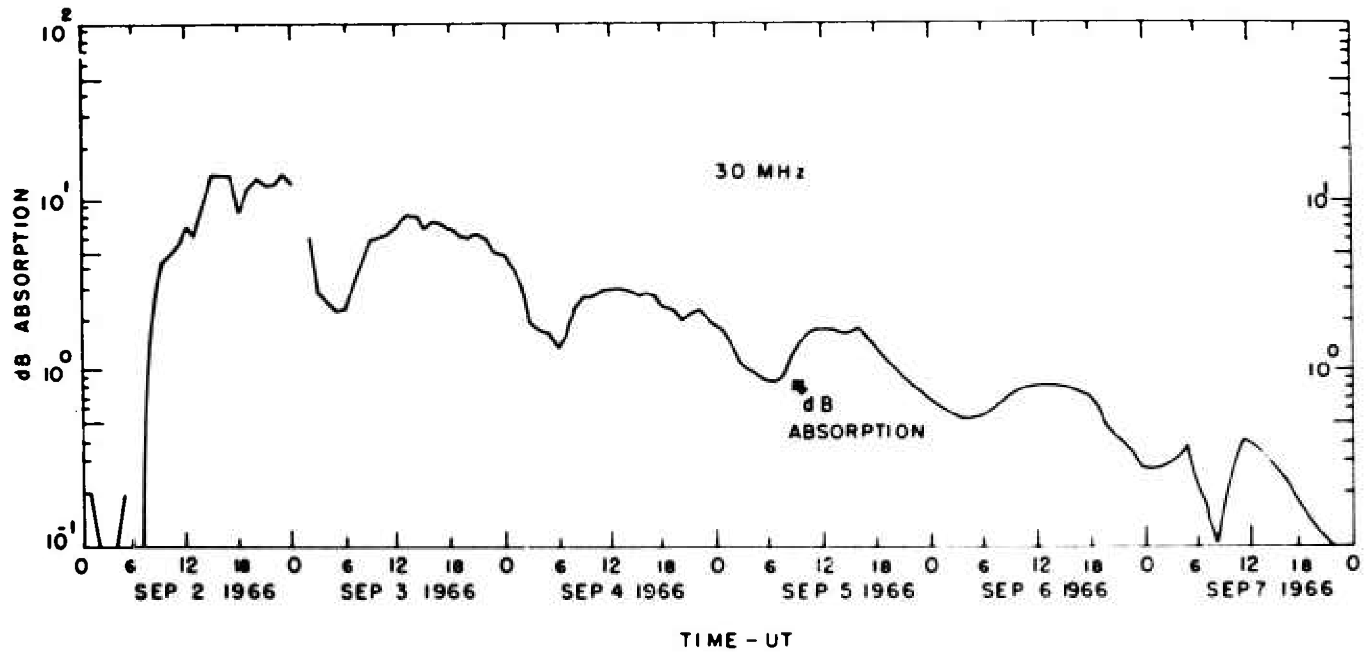
Plot 3 Mar. 24, 1966



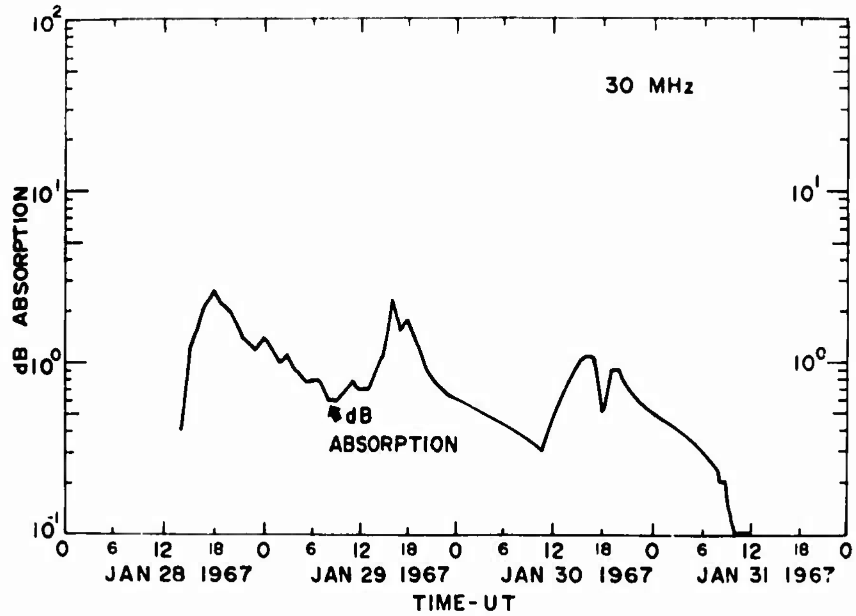
Plot 4 July 7, 1966



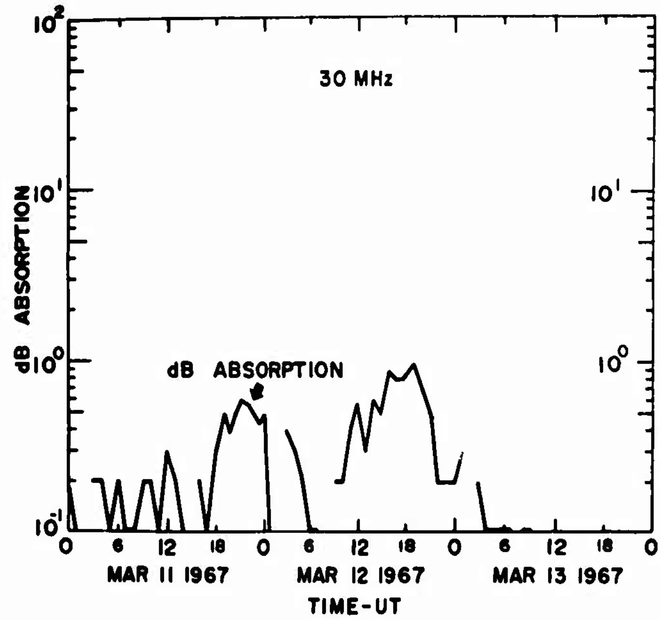
Plot 5 Aug. 28, 1966



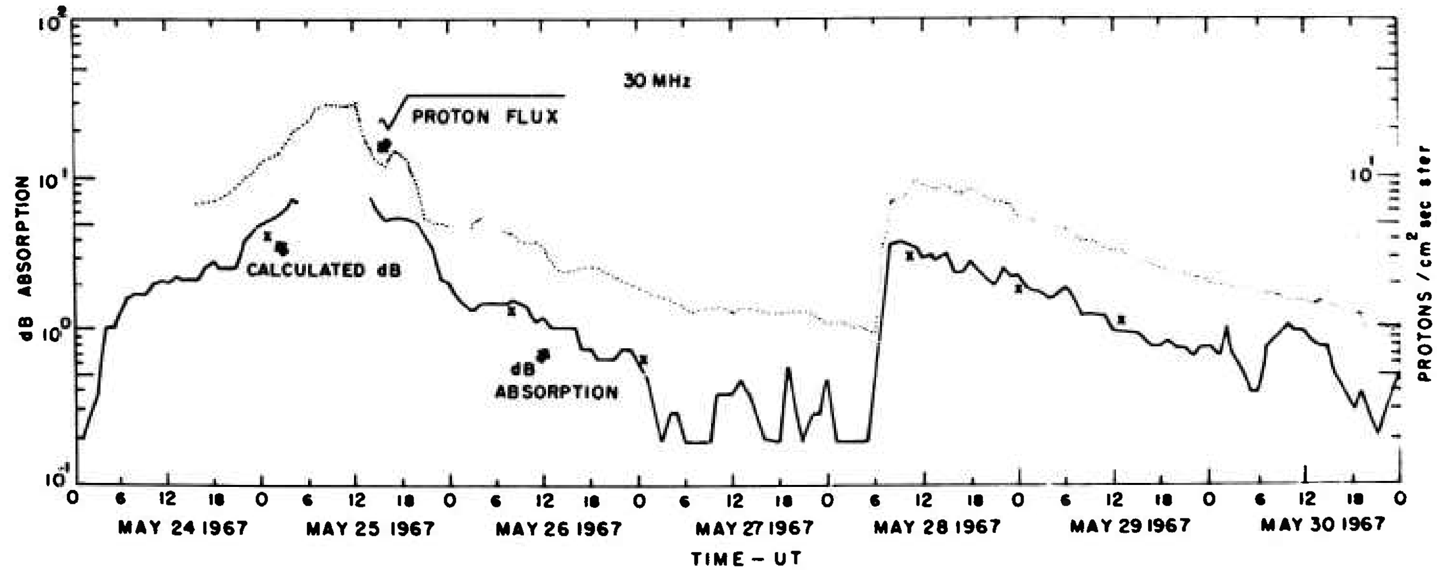
Plot 6 Sept. 2, 1966



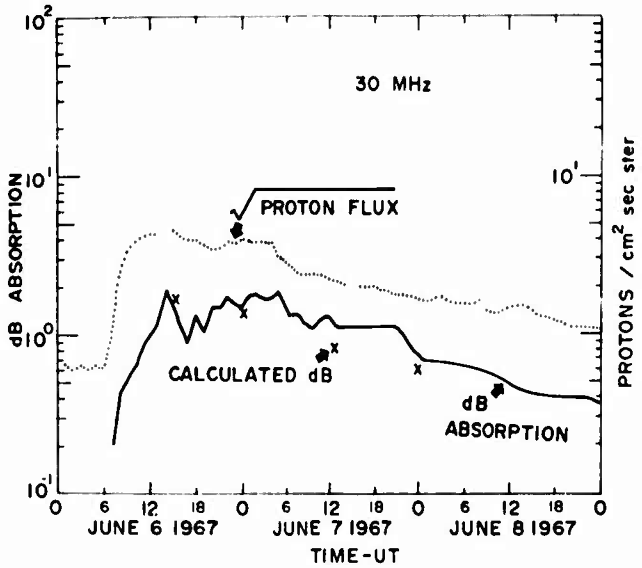
Plot 7 Jan. 28, 1967



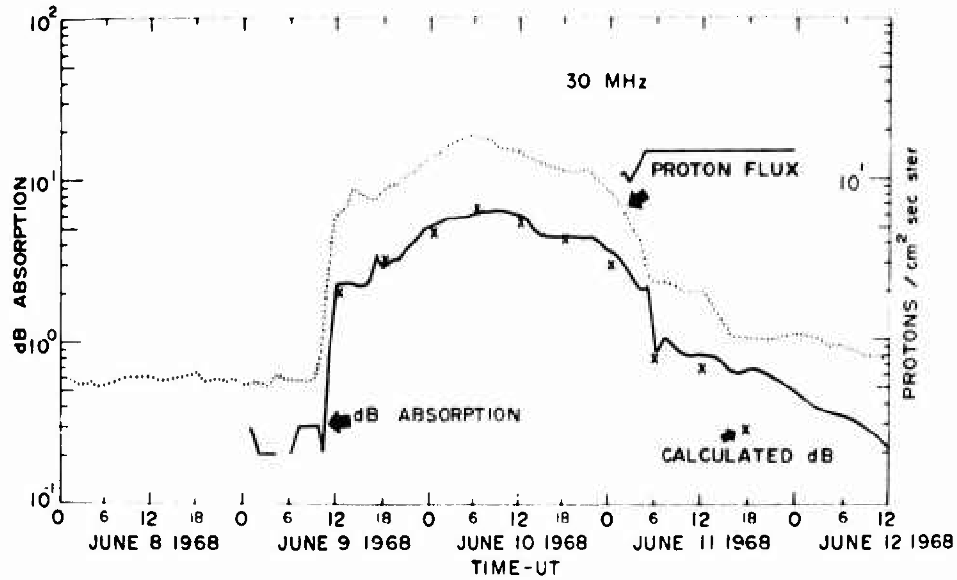
Plot 8 Mar. 11, 1967



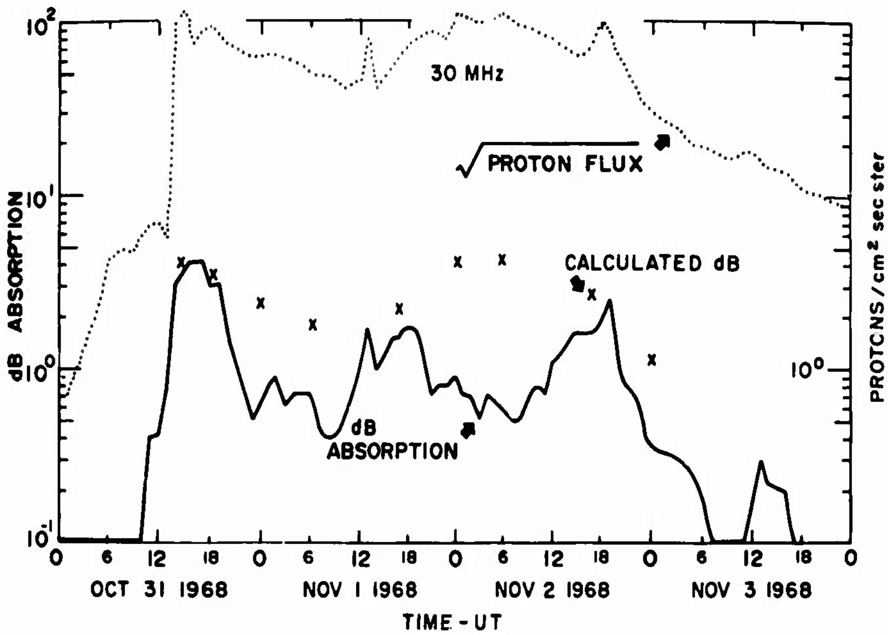
Plot 9 May 24 & May 28, 1967



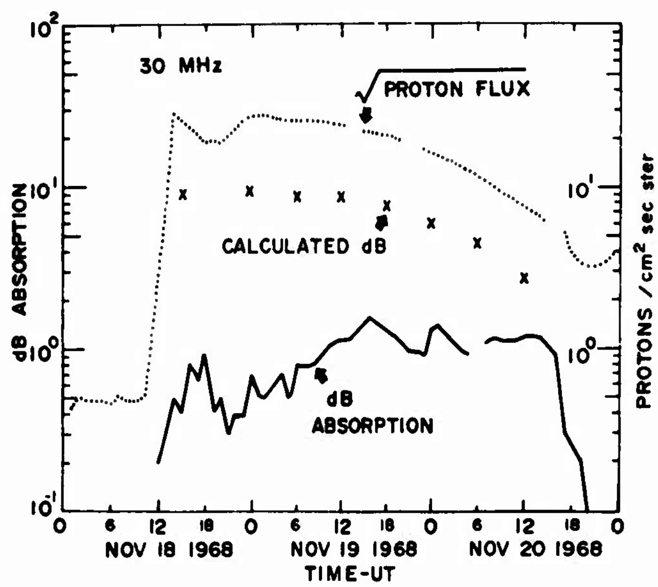
Plot 10 June 6, 1967



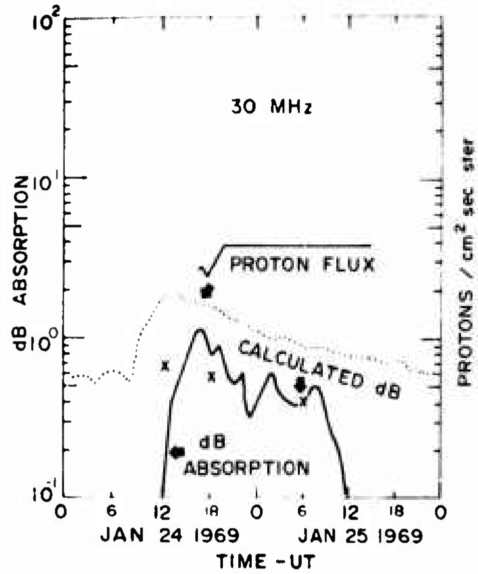
Plot 11 June 9, 1968



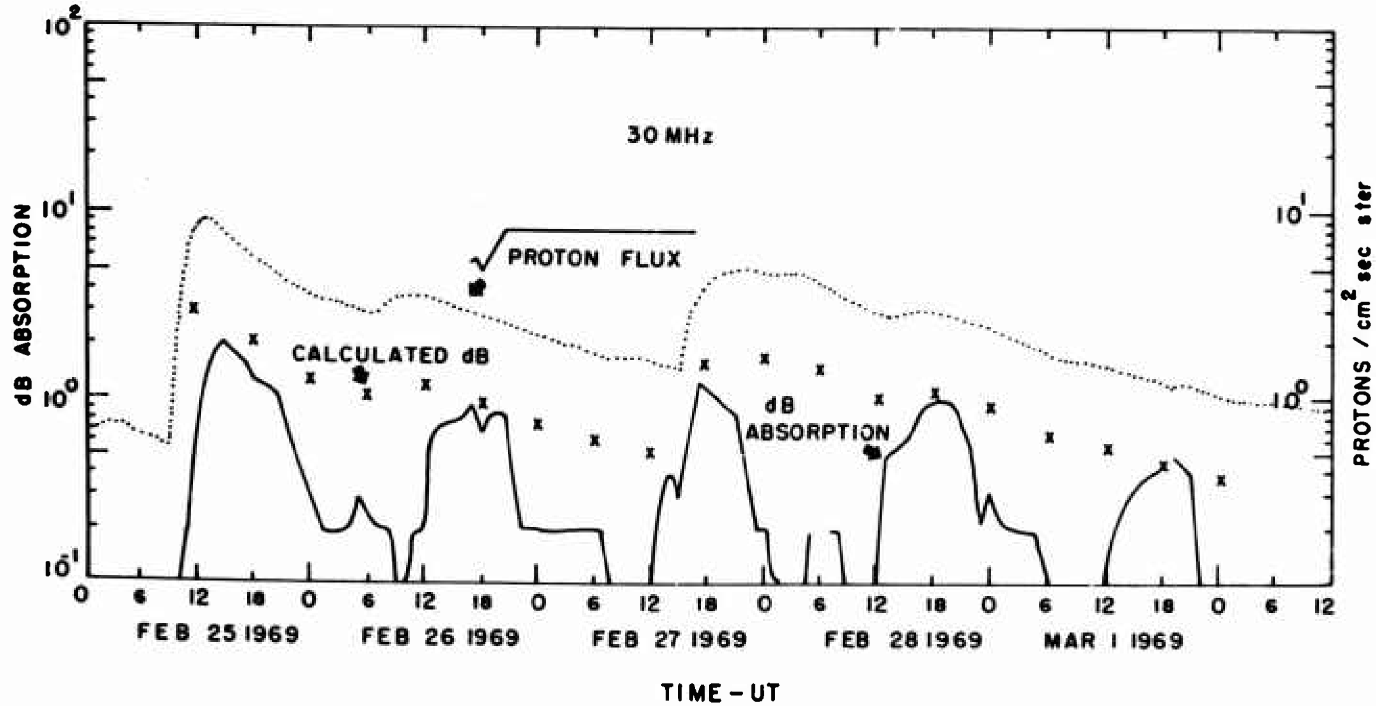
Plot 12 Oct. 31, 1968



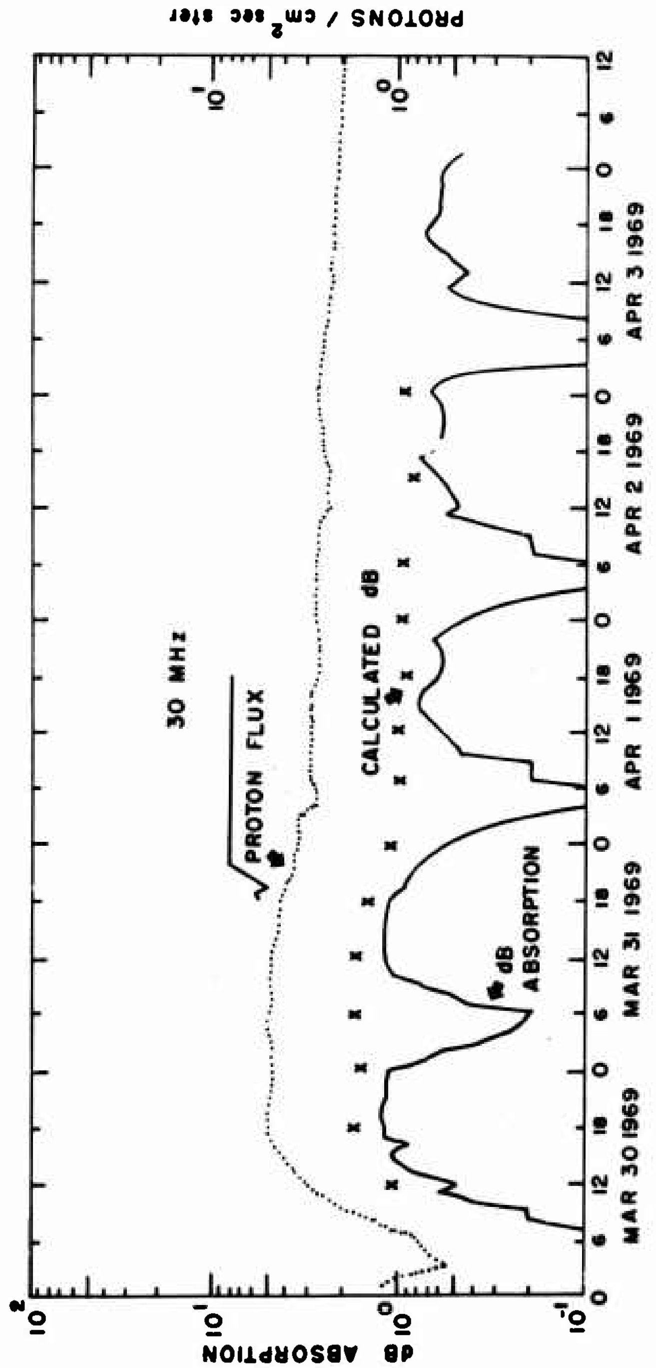
Plot 13 Nov. 18, 1968



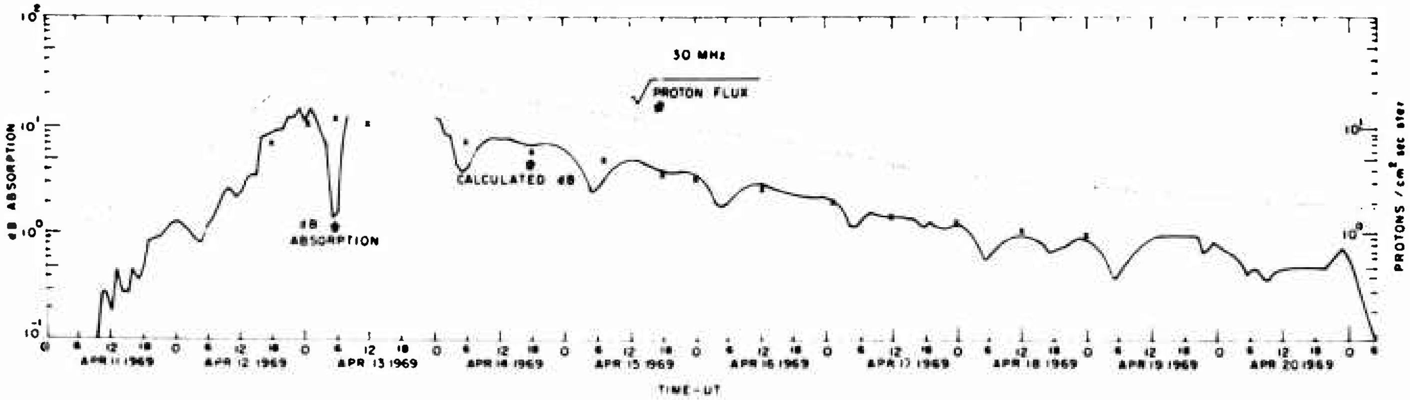
Plot 14 Jan. 24, 1969



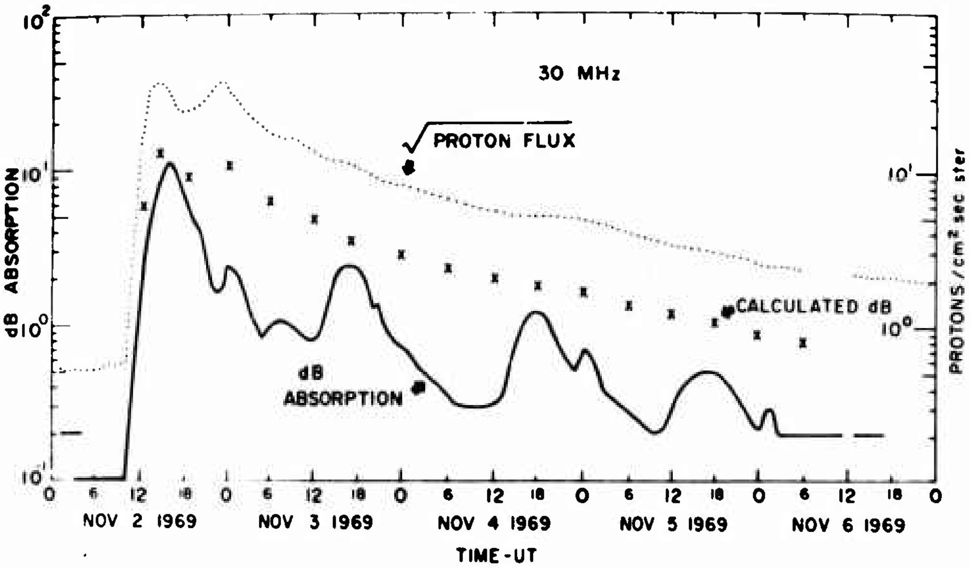
Plot 15 Feb. 25, 1969



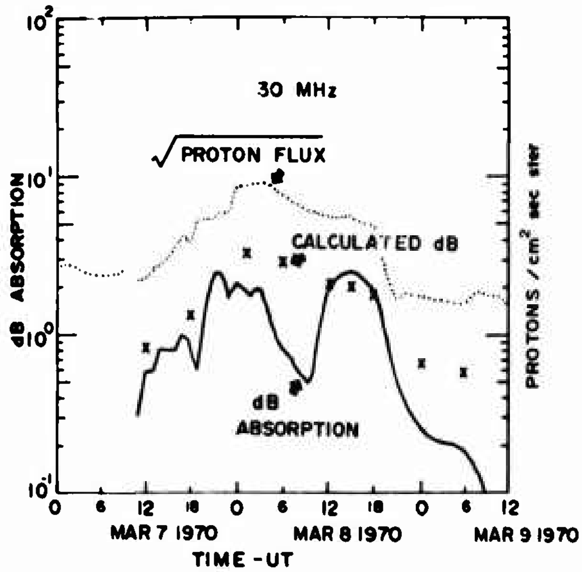
Plot 16 Mar. 30, 1969



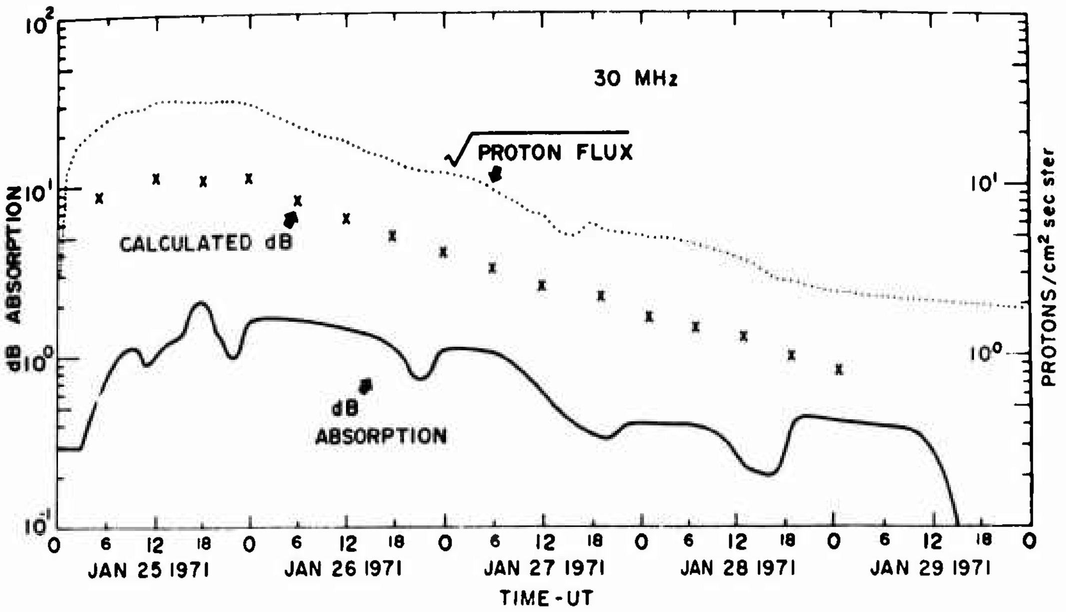
Plot 17 April 11, 1969



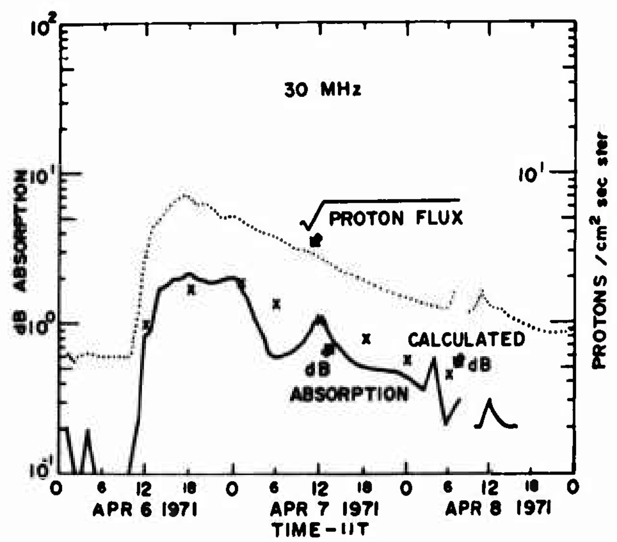
Plot 18   Nov. 2, 1969



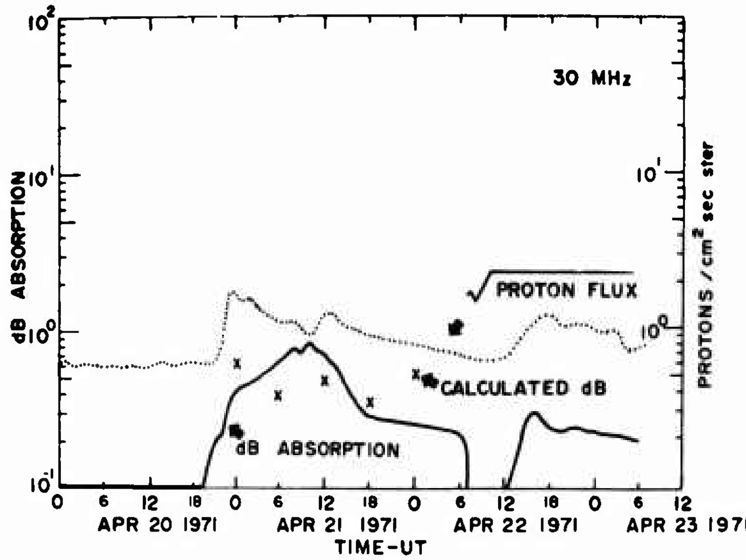
Plot 19   Mar. 7, 1970



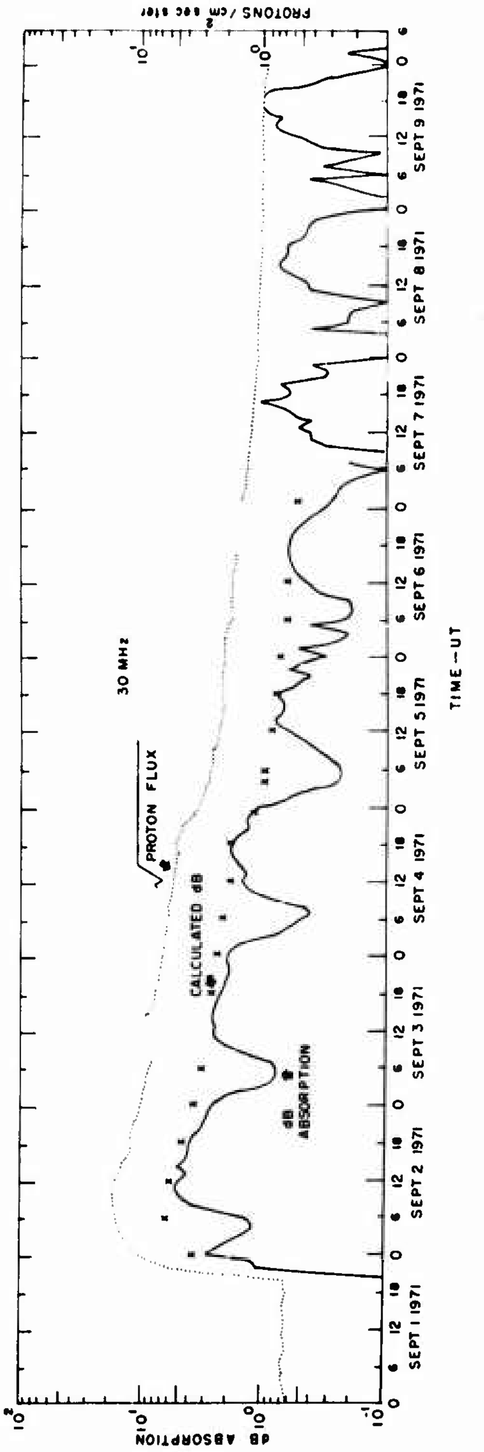
Plot 20 Jan. 25, 1971



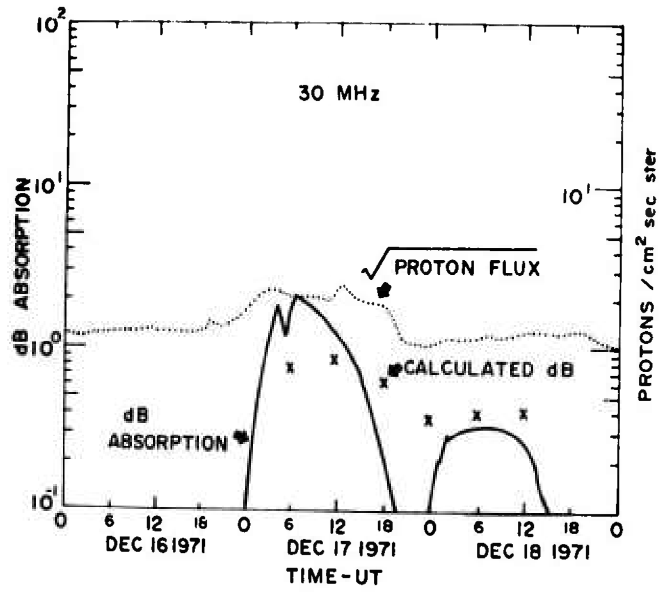
Plot 21 Apr. 6, 1971



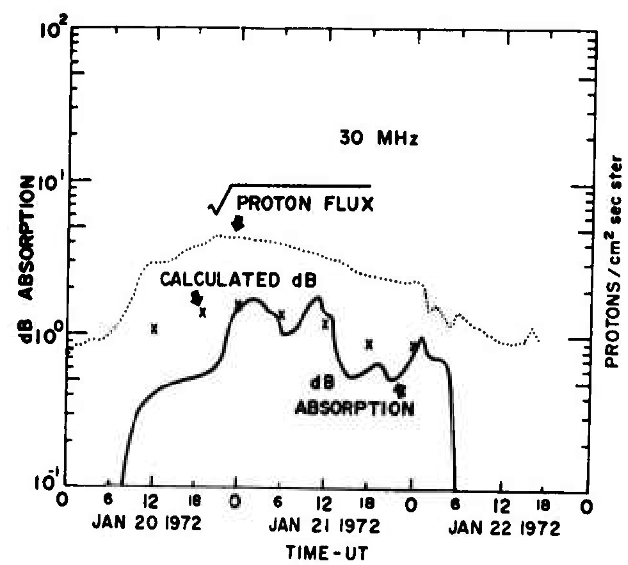
Plot 22 April 21, 1971



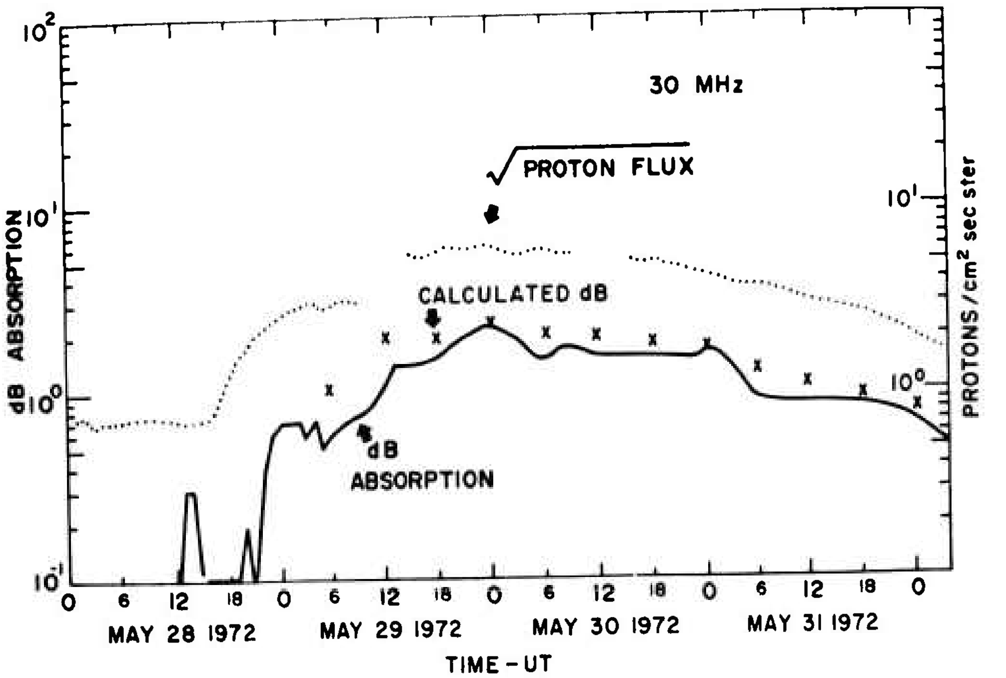
Plot 23 Sept. 1, 1971



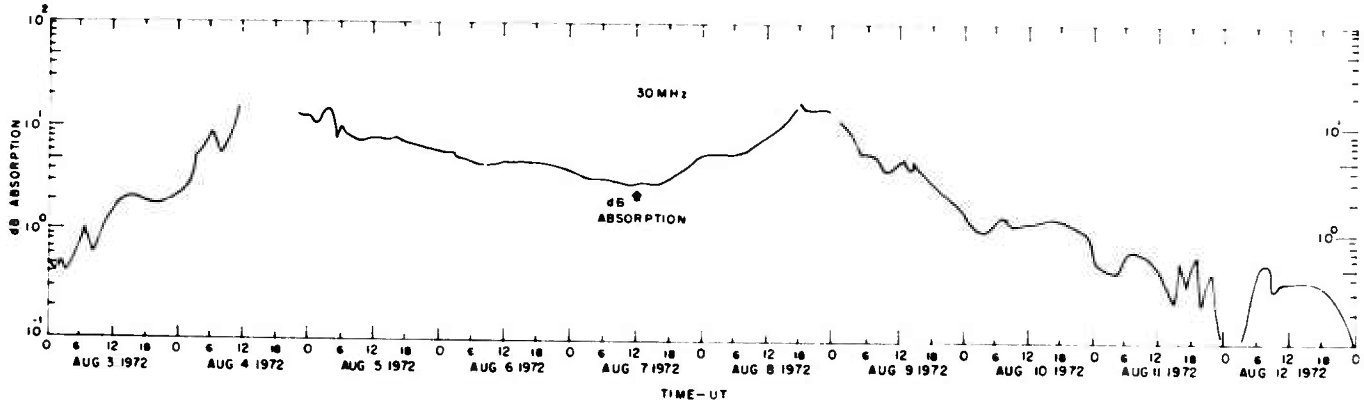
Plot 24   Dec. 17, 1971



Plot 25   Jan. 20, 1972



Plot 26 May 28, 1972



Plot 27 Aug. 3 & Aug. 7, 1972